EDUCATION MODULE: Exploring Solar Power

Author: Brittany Walker

Subject and Grade Level: High school science; best with a 9th or 10th grade integrated or physical science class.

National Science Standards Addressed:
Standard A, Science as Inquiry: Abilities necessary to do scientific inquiry
Standard B, Physical Science: Interactions of energy and matter
Standard E, Science and Technology: Understandings about science and technology

Overview: In this activity, students will discover the basic principles behind solar power and electronics. Much graphing is required for this activity, so knowledge of graphing is required. The teacher may choose to have the students use a graphing program such as Excel to complete their graphs.

Purpose: The purpose of this activity is to allow students to explore the basic ideas behind solar power, including electronics, solar panels, position of the sun, position and tilt angle of the modules, and shading of the module. Through exploration, the students should gain a better understanding of these principles and how they contribute to solar power.

Learning Objectives: By the completion of this activity, students should be able:

- To work a multimeter to measure voltage and current
- To determine the position and tilt angle for the module to produce the highest power at a given time
- To explain how voltage, current, and power change with different tilt angles on the module
- To explain how voltage and current affect power
- To explain how position and tilt angle affect the power output of a module
- To explain how shading affects the power output of a module
- To determine if cells are connected in series or parallel
- To explain differences between class results for best tilt angle and position in relation to the changing position of the sun
- To predict solar noon

Vocabulary: Before the beginning of this activity, students should have a basic knowledge of the following words:

- solar power
- current
- voltage
- power
- series connection
- parallel connection

Resources and Materials:
small PV modules and a multimeter for each module (number depends on class size and how many you wish to place in a group), protractors, calculators, compass, Excel or other graphing program (not necessary, but helpful), and a sunny day!

Preparatory Activities: Prior to this activity, students should know:

- The difference between a series and parallel connection, that in a series connection the voltages are added and in a parallel connection the currents are added
- The very basics of how a solar panel works (the basics of how it converts sunlight to energy), and the difference between a cell and a panel. Although not much knowledge of solar energy is necessary for this lab, the teacher may desire to spend a day prior to this activity introducing solar energy and discussing some of the advantages and disadvantages of its use.
- Knowledge of Excel or some other graphing software program is helpful to complete this activity since a large amount of graphing is required. However, the teacher may choose not to use such software based on the ability of the students and the available resources. Students can make the graphs manually in place of the graphing software. Most importantly, students need to have a good background in graphing.

Main Activities:

Note: The following schedule of events is merely a suggestion. The teacher for this activity should allot time according to the needs of his/her class based on class period time and the students' knowledge. The suggested schedule assumes 2 ninety-minute block periods. But, this lesson can be broken into several segments if needed. It is important to note, however, that the measurements for Parts 2 and 3 should be made on the same day.

<u>Day One: Introduction and Measurements</u>

- The students should be broken into groups of 3 or 4 based on class size and number of supplies. Each group needs one PV module, a multimeter, a compass, and a protractor. (5 minutes).
- Assuming the students have not used a multimeter prior to this lab, the teacher should run a practice session, demonstrating how to use the multimeter to measure both current and voltage. Each group should practice these measurements inside the classroom before making measurements outside. (20 minutes).
- Once each group has demonstrated the ability to measure current and voltage with the multimeter, the class should move outside to make their experimental measurements (5 minutes).
- The students will make their measurements for Parts 2, 3, and 4. The students should write the procedures and required hypothesis in their lab notebooks, along with corresponding data tables and answers to questions. The students should not work on any of the italicized instruction or questions until they have completed their measurements for Parts 2, 3, and 4. (55 minutes).
- The class will return back to the classroom and return supplies to their proper place. (5 minutes).

Day Two: Analysis of Lab

- The students should work individually on the analysis of this lab, especially for Parts 2, 3, and 4. The whole class period should be dedicated to allow students to work on the italicized portions of the lab that they did not work on the previous day. The analysis requires a large amount of graphing and access to Excel or another graphing software would be helpful. However, the teacher may request that the students do their graphing manually. (90 minutes)
- About 15 minutes before the end of class, the students should have all written down their answer from question #5, Part 3 on the board. At this point in time, the class should discuss and devise a method for determining the overall class result for the best position and tilt angle of the PV module.
- Students should finish Part 5 for homework.

Note to teacher: This lab should be "de-briefed" the next day in class. At this time, the teacher should allow about 15 minutes for a class discussion on the most important findings of the lab, and to address any issues that might be confusing for the students. This de-briefing period is essential to helping students' tie information together and this time should not be overlooked!

Name:____

EXPLORING SOLAR POWER

In this activity we will discover the basic principles behind solar power and electronics. Please note that any italicized writing refers to analysis activities that are best done after the collection of all of your data. For instance, your teacher may require you to collect data for all five parts before you begin actually interpreting this data.

Part One: Setting up the Photovoltaics and Multimeter

Draw a picture in your lab notebook that shows how you have connected your module to your multimeter. Don't forget to include positive (red) and negative (black) connections. Also, make sure to label you're drawing!

Part Two: Tilt Angle

How do voltage, current, and power change in relation to the angles of the module? How are voltage, current, and power related?

Before you begin this experiment, be sure to write a 1-2 sentence summary of the procedure and make a data table in your notebook to record voltage, current, and power for each angle being measured. You do not need to write a hypothesis for this portion of the experiment.

Use a leveler to create a surface where the PV module can lie completely horizontal. This will be a 0° angle. Measure current and voltage with the multimeter at this angle. Using a protractor, adjust the PV module so that it is tilted 22.5° from horizontal. Measure and record the corresponding voltage and current at this angle. Perform the same procedure for 45°, 67.5°, and 90°. Be sure to note the time in your notebook.

1. Calculate the power for each angle. At which angle listed above does the PV module produce the highest power?

Devise a test to determine the angle at which the PV module can produce the highest power (at this time, on this day). Write the procedure for this test in your lab notebook, write your hypothesis, and then perform your experiment. Again, be sure to record the time in your notebook.

2. According to your data, at which angle does the PV module produce the highest power? Be sure to note the time of day and date in your answer! (Ex. At 10:15 am on Oct. 14, 2001, the PV module produced a maximum power of _____).

Use Excel to plot the angle vs. voltage, current, and power. You should create three separate graphs in order to properly plot this information. Also, make all of the graphs the same size so that you can compare among the graphs easily. Be sure to include all of the data you acquired to answer #1 and at least some of the data acquired to answer #2.

3. *Based on the graphs you created, can you define any relationship between angle and the three dependent variables (voltage, current, and power)? If so, what? Explain.*

4. *Based on the 3 graphs, did current or voltage have a greater affect on your calculations for power? How do you know?*

5. *Write a conclusion for this part of the lab that is about 5 sentences long. Do not forget to compare your hypothesis to your results!*

Part Three: Positions

How do voltage, current, and power change in relation to the position of the module?

This part of our investigation is very similar to that in Part Two, except that in this part we will be changing the angles that the module is positioned instead of the tilt angle.

Here, you are required to measure current and voltage at the following positions: 0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315°. You can measure the degrees of position by using a compass, where 0° represents magnetic north. Also, you should be sure to use a tilt angle close to the one that gave you maximum power in Part Two. Be sure to write a procedure for this experiment, record the time of day, perform the experiment, and record your data in the form of a data table in your lab notebook. You do not need to write a hypothesis for this part of the procedure.

1. Calculate the power for each position. At which position listed above does the PV module produce the highest power?

Devise a test to determine the position that the PV module can produce the highest power (at this time, on this day). Write the procedure for this test, write your hypothesis, perform your experiment, and record your data in your lab notebook.

2. According to your data, at which position does the PV module produce the highest power? Be sure to note the time of day and date in your answer!

3. *Plot position (in degrees) vs. power. Be sure to use all of the data you acquired to answer #1 and at least some of the data you acquired to answer #2. What relationship do you see? Why do you think this relationship exists?*

4. *From what you have learned in Parts Two and Three, how should you place your PV module during your class period to allow the module to produce the most power?*

5. *Place your results from #4 on the board for the rest of the class to see.*

6. *Write a conclusion for this part of the lab that is about 5 sentences long. Do not forget to compare your hypothesis to your results!*

<u>Part Four: Shading</u>

How does shading affect the power that the PV module is able to produce?

Cut 4 pieces of paper that are 1/4 of the size of the module. Use one of the pieces of paper to cover 1/4 of the module. Draw a picture of the module and which portion you have covered in your lab notebook. Next to each picture, record the corresponding voltage and current. Perform the same procedure when covering 1/2, 3/4, and 100% of the module. Be sure to make a drawing and record the corresponding voltage and current for each shading increment!

1. Which cells are connected in series? Which cells are connected in parallel? (You may draw a diagram if this helps you) How do you know?

2. *Why do you think it is important to keep PV modules away from trees and other shadow- causing obstructions?*

3. *Write a conclusion for this part of the lab that is about 3 sentences long.*

<u>Part Five: Optimum Comparison</u>

In this part you will use your own class's values and values from other classes from question #6 in Part Three to answer these questions.

1. What did your class determine to be the best position and tilt angle to place the PV module to get the highest power during your class period? How did your class decide this?

2. Write down the best position and tilt angle determined from the other classes. Make sure to include the time that the class measured these variables. Were the results from your class different from those of the other classes? If so, why do you think this happened?

Using Excel, make two graphs based on the data you have obtained from all of the classes. The first graph should show time vs. best position. The second graph should show time vs. best tilt angle.

3. *Solar noon is the time of day that the sun is the highest in the sky. This changes from day to day based on the position of the earth and other factors such as "daylight savings". Based on these graphs, at what time do you think solar noon happened on this day of measurement? How did you come to this conclusion?*

4. *Write a conclusion for this part of the experiment that is about 5 sentences long.*

GRADING RUBRIC

Note: "required" refers to all times when the lab worksheet requested work in the designated category.

	5	4	3	0
Drawings	All required drawings included; drawings labeled properly	All required drawings included; some things not labeled properly	Most, but not all drawings required included; drawings mostly labeled properly but may have a few errors	Did not meet minimum passing requirements
Procedures	All required procedures included; procedures are correct	All required procedures included; some aspects of procedures may not be correct	Most, but not all required procedures included; procedures mostly correct but may have a few errors	Did not meet minimum passing requirements
Hypothesis	All required hypothesis included; all are stated in complete sentences.	All required hypothesis included; some not stated in complete sentences.	Most, but not all required hypothesis included; some not stated in complete sentences.	Did not meet minimum passing requirements
Data	All required data collected; data is reasonable; data presented in tables when required	All required data is collected; some data not reasonable and/or not presented in data tables when required	Most, but not all required data is collected; some data not reasonable and/or not presented in data tables when required	Did not meet minimum passing requirements
Power Calculations	All required power calculations determined; calculations are correct	All required power calculations determined; some calculations not correct	Most, but not all required power calculations determined; some calculations not correct	Did not meet minimum passing requirements
Questions	All questions answered; answers are in complete sentences; all answers are correct and/or based on reasonable logic	All questions answered; some answers are not in complete sentences; some answers are in correct and/or not based on reasonable logic	Most, but not all questions answered; some answers are not in complete sentences; some answers are in correct and/or not based on reasonable logic	Did not meet minimum passing requirements
Graphs	All required graphs created; graphs have proper titles and axis labels with units; axis are correctly placed	All required graphs created; some graphs do not have proper titles and/or axis labels with units; axis may be incorrectly placed	Most, but not all required graphs created; some graphs do not have proper titles and/or axis labels with units; axis may be incorrectly placed	Did not meet minimum passing requirements
Conclusions	All required conclusions written; conclusions written in complete sentences; conclusions are correct and/or based on reasonable logic	All required conclusions written; some conclusions not written in complete sentences; some conclusions not correct and/or not based on reasonable logic	Most, but not all required conclusions written; some conclusions not written in complete sentences; some conclusions not correct and/or not based on reasonable logic	Did not meet minimum passing requirements